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1 Introduction

Comprehension is vital and is the ultimate goal of reading (Nation & Norbury, 2005) and, although reading fluency (automatic word recognition) is necessary for students to achieve comprehension (Moats, 1998), decoding skill does not necessarily mean that comprehension will follow (Nation & Norbury, 2005). Opportunity to read is significantly associated with reading achievement (Guthrie, Schafer & Huang, 2001). In order to become independent readers, children need to be provided with a wide range of reading experiences (Cunningham & Stanovich, 2001). Getting children to read more, especially outside of school, although vital for improving reading skill, is very difficult to achieve. The National Literacy Trust survey (Clark, 2014a) found that only 41% of 8-11 year olds read outside class daily, with 12% rarely or never reading outside of school (16% of boys and 8% of girls). The survey also found that 27% of children said that their parents don't care whether they spend any time reading and 47% state that they prefer watching television to reading (Clark, 2014a). Despite continual increases in reading standards over the last 17 years, 11% of English 11-year-olds do not meet the expected level (Level 4 or higher) in their SATs reading test (DfE, 2014). This figure is higher (18%) for pupils eligible for free school meals. Poor readers will miss out on a good deal of academic content due to their inability to acquire knowledge from text reading (Carnine & Carnine, 2004; Montali & Lewandowski, 1996; Visone, 2010) and

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the requirement to learn from reading text increases as students progress through their education (Williams, 1998). Beyond education, research has shown poor literacy to be related to unemployment, low pay, poor health and offending (Morrisroe, 2014).

Reading fluency is essential for reading success (Hasbrouck & Tindal, 2006; Speece & Ritchey, 2005). A child who is fluent in reading is able to recognise the majority of words in a text quickly and without relying on phonological decoding. Reading fluency requires a large amount of practice to become established and a lack of practice in reading and exposure to text negatively affects the automaticity and speed of word recognition (Cunningham & Stanovich, 2001). Poor decoding makes reading arduous and leads to errors and misreading of words (Torgesen, 2002) affecting the development of fluent word reading, which slows down the reading process and diverts effort away from understanding the meaning of the text (Hudson, Lane & Pullen, 2005). Children who lack fluency in word decoding will have difficulty reading independently and their comprehension will be impaired (Ehri, 2005; Fuchs, Fuchs, Hosp & Jenkins, 2001; McKenna, 1998; Stanovich, 1986). Torgesen and Barker (1995) suggest that the majority of children with reading difficulties do not receive sufficient practice at decoding to reach a level of fluency that will allow them to read effectively. Due to their difficulty in phonological decoding, these children require far more practice and exposure to text to become fluent in word recognition (Ehri, 2005).

Reading comprehension problems have also been attributed to deficits in vocabulary knowledge (Beck, Perfetti & McKeown, 1982). If a child comes across a word that is not in his or her vocabulary then they are unlikely to identify it, even using phonological decoding. Furthermore, the higher the proportion of unfamiliar words within a text, the more likely it is that comprehension will be impaired. Pickering and

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Gathercole (2004) suggest that the poor phonological storage skills of children with language difficulties may lead to early difficulties in acquiring new vocabulary. In addition, research has found that the relation between reading ability and vocabulary knowledge is reciprocal – children who read widely increase their vocabulary knowledge and are able to comprehend a wider variety of texts, thus increasing their reading experience and developing their vocabulary further (Cunningham & Allington, 2010). Lovett, Barron and Benson (2003) stress the importance of text reading practice using a controlled decodable vocabulary.

Reading comprehension also requires complex thought processes, such as relating information in the text to wider knowledge, drawing inferences and making deductions. Cain and Oakhill (1999) found children with comprehension difficulties to be poor at inference-making and further research has shown that the relation between comprehension ability and inference-making skill remains strong when knowledge base is controlled for (Cain, Oakhill, Barnes & Bryant, 2001). However, an inference cannot be made without the ability to relate the information in the text to wider knowledge (Ackerman, Silver & Glickman, 1990). Much experience is required to develop these thinking skills and instruction that promotes critical thinking and considering alternatives in decision-making has been shown to augment reading comprehension (Fletcher, Lyon, Fuchs & Barnes, 2007).

Motivation is also essential for reading progress. Research has shown a bidirectional relation between reading ability and motivation to read (Morgan & Fuchs, 2007); good readers tend to enjoy reading and so read more, thus improving their ability further, whilst struggling readers tend not to enjoy reading (McKenna, 1998) and so read less, falling further behind their peers (Hasbrouck, Ihnot & Rogers, 1999) – this is

known as the ‘Matthew Effect’ (Stanovich, 1986). It has been suggested that the lack of motivation seen in children at risk of reading difficulty occurs within a year of starting school (Chapman, Tunmer & Prochnow, 2000). Children with reading difficulties are the most likely to benefit from reading practice but the least motivated to carry this out (Chapman, 1988).

Several researchers have shown independent silent reading to be beneficial in terms of reading achievement, comprehension, fluency and vocabulary (Kelley & Clausen-Grace, 2006; Reutzel, Fawson & Smith, 2008; Reutzel, Jones, Fawson & Smith, 2008), particularly for students over the age of 8 years old (Kuhn, 2004; Reutzel, Petscher & Spichtig, 2012). However, there are some issues with using independent silent reading practice in the classroom, such as ensuring that students are actually able to read the books they choose (Donovan, Smolkin & Lomax, 2000) and keeping their eyes on the text (Hiebert, Wilson & Trainin, 2010). Nevertheless, research has shown computer-based guided silent reading interventions, using texts which increase in difficulty and length, to produce gains in reading comprehension and general literacy achievement (Rasinski, Samuels, Hiebert, Petscher & Feller, 2011; Reutzel et al., 2012). Reutzel et al. suggest that the success of the computer-based guided intervention is due to the program monitoring the children’s comprehension and adjusting the text level to suit their ability (rather than children selecting texts that are too difficult for them), promoting motivation by giving students a choice of genre within the appropriate level of text, making students accountable for their time by monitoring their progress and focusing on the development of fluency, vocabulary and comprehension skills.

Reading aloud to children has been found to have a positive impact on language, phonological awareness, print concepts, comprehension and vocabulary (Swanson et al.,

2011), and is especially effective when it involves repeated reading, vocabulary instruction and questioning (Karweit & Wasik, 1996). Repeated reading of passages or stories, either independently or reading along, has been found to develop reading rate, accuracy, expression, comprehension and retention of information (Armstrong & Hughes, 2012; Barnett & Seefeldt, 1989; Nelson, Alber & Gordy, 2004; Pappas & Brown, 1987; Therrien, Wickstrom & Jones, 2006). Computer interventions involving reading aloud with a computer have also been seen to be effective in increasing comprehension (Basil & Reyes, 2003; Swanson et al., 2011). It has been suggested that the provision of increasingly difficult text, along with corrective feedback is imperative for an improvement in reading (Chard, Vaughn & Tyler, 2002). Hall, Hughes and Filbert (2000) suggest that strategic feedback must include a review process where students return to questions answered incorrectly before moving on to new tasks.

Hatcher, Hulme and Snowling (2004) argue that mainstream teaching does not generally enable children at-risk of reading difficulties to develop fluent and accurate reading and research suggests that this group of children need an individualised approach (Torgesen, 2005). However, Torgesen, Alexander, Wagner, Rashotte, Voeller and Conway (2001) purport that, although special education reading instruction is more effective than classroom instruction, it is not enough to bring reading disabled children's reading up to average levels. Due to their difficulty in phonological decoding, these children require far more practice and exposure to text to become fluent in word recognition (Ehri, 2005). However, teachers looking for strategies to improve the decoding and comprehension skills of poor readers are limited in the amount of instruction and practice they can provide due to teacher shortages, school finances and time factors (Fielding, Kerr & Rosier, 2007; Gibson, Cartledge & Keyes, 2011; Hall et

al., 2000). Furthermore, Moats (1999) suggests that many teachers are not adequately trained to provide the specific instruction necessary for students at risk of reading disabilities.

Researchers have stressed the importance of technology in supporting struggling readers by providing the intensive, individualised instruction and extensive repeated practice that they require (Hasselbring & Goin, 2004; Torgesen, 2002), allowing children to work at their own pace with the provision of immediate feedback and instructive corrections (Hall et al., 2000) along with efficient monitoring of student progress (Kim, Vaughn, Klingner, Woodruff, Klein Reutebuch & Kouzekanani, 2006). The adaptive nature of computerised learning tools makes them more effective as slower learners get more practice before progressing on to subsequent stages (McDonald Connor et al., 2009). Furthermore, this specialised instruction can be provided at a low cost but with high reliability (Torgesen, Wagner, Rashotte, Herron & Lindamood, 2010), whereas teachers are not always able to apply interventions with this high level of integrity (Moore & Fisher, 2007). A number of studies have found that using technology in reading activities, not only benefits reading ability, but also improves self-confidence and motivation (Adam & Wild, 1997; Hall et al., 2000; Mioduser, Tur-Kaspa & Leitner, 2000; Moore & Calvert, 2000) and reduces behavioural problems during instruction (Chen & Bernard-Opitz, 1993). Furthermore, some researchers have shown middle school pupils to show higher levels of motivation in reading digital resources than print based ones for recreational purposes (McKenna, Conradi, Lawrence, Jang & Meyer, 2012; O'Brien, Beach & Scharber, 2007). Indeed, the reading of technology-based formats (text messages, websites and digital magazines) are shown to be most commonly read outside of school, and the proportion

of children and young people reading ebooks has risen from 11.9% in 2012 to 14.3% in 2013 (Clark, 2014b). By keeping struggling readers motivated, they are less likely to give up (Karemaker, Pitchford & O'Malley, 2010), which may help overcome the 'Matthew Effect'. Furthermore, the use of computerised reading instruction allows teachers more time to work individually with students who need particular help (Carnine, 1989, cited in Kim et al., 2006).

Several researchers have shown computerised reading interventions to be effective for improving letter knowledge, phonological skills, word reading and spelling across a number of languages (Brem et al., 2010; Huemer, Landerl, Aron & Lyytinen, 2008; Kyle, Kujala, Richardson, Lyytinen & Goswami, 2013; Lonigan, Driscoll, Phillips, Cantor, Anthony & Goldstein, 2003; Savage, Abrami, Higgs & Deault, 2009; Saine, Lerkkanen, Ahonen, Tolvanen & Lyytinen, 2011). Furthermore, other studies have shown computerised interventions to be effective at increasing reading comprehension in relatively short time periods of up to 16 weeks, with pupils enjoying the programs and wishing to continue using them (Gibson et al., 2011; Kim et al., 2006; Torgesen et al., 2010). However, there is little evidence of significant increases in reading rate in previous studies. Indeed, Torgesen et al. (2001) suggest that rate may not significantly improve due to the nature of reading comprehension tests. Post intervention, participants progress further through tests and therefore encounter harder passages with more unfamiliar words, which take longer to decode. They argue that increasing the reading rate of older poor readers is challenging as their previous lack of exposure to text limits their reading fluency.

Notwithstanding the recognised advantages of computerised reading programs, Gibson et al. (2011) argue that many commercial programs are being used in

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classrooms without the empirical research to support their use. Karemaker et al. (2010) suggest that the majority of previous research studies on computer-assisted reading instruction are based on programs that present words in isolation, rather than storybook formats, and are not based in the natural classroom setting, making them less valid in terms of educational practice. Furthermore, Saine, Lerkkanen, Ahonen, Tolvanen and Lyytinen (2013) assert that most previous studies of computerised reading interventions have not used control groups who continue in mainstream instruction, rather than taking part in a specialist intervention program, and many do not report effect sizes.

Galuschka, Ise, Krick and Schulte-Korne (2014) support the assertion that research into reading programs should utilise randomised controlled trials.

Comprehension Booster is a computer program that provides pupils with interactive reading practice using a variety of texts, and opportunities to acquire new vocabulary and learn the thinking skills required for understanding text (Lucid Innovations, 2010). It is possible to set specific teaching plans for individual children or whole classes and speech can be enabled or disabled, according to pupil needs. Reports generated by the program allow each child's progress to be constantly monitored.

Comprehension Booster utilises several of the methods identified as being effective in improving reading comprehension, including silent reading (Kuhn, 2004; Reutzel et al., 2008; Reutzel et al., 2012), repeated reading (Armstrong & Hughes, 2012; Karweit & Wasik, 1996; Therrien et al., 2006), controlled decodable vocabulary and vocabulary instruction (Karweit & Wasik, 1996; Lovett et al., 2003), reading along with the computer (Basil & Reyes, 2003; Swanson et al., 2011), increasingly difficult text (Chard et al., 2002), question and answering (Karweit & Wasik, 1996) and immediate

corrective feedback (Chard et al., 2002) allowing the child to reflect on the responses given before moving on to the next passage (Hall et al., 2000).

The aim of the present study is to investigate the effectiveness of Comprehension Booster in developing the reading accuracy, reading fluency and reading comprehension of primary school children with reading difficulties, using a randomised controlled trial. The current study is designed to fill a gap in the literature as there is currently no published evidence of the effectiveness of this program. Indeed, there is a paucity of studies looking at the effectiveness of computerised reading interventions in UK primary schools.

The hypotheses are: 1) there will be significantly more improvement in reading accuracy and reading comprehension, from baseline to post-test, in the intervention group than in the control group; 2) there will be no significant difference between the intervention and control group in improvement shown in reading rate from baseline to post-test.

2 Method

2.1 *Participants*

The 38 participants attended two primary schools in the north of England. These schools were selected due to them having above average numbers of disadvantaged children (as measured by Free School Meal data), high numbers of pupils with Special Educational Needs (SEN; as measured by School Action Plus and Statement data) and low levels of attainment in reading (as measured by Key Stage 2 test data). Both

schools' most recent Ofsted reports rated them as requiring improvement. Summary data (percentages and quintile scores) for both schools are presented in Table 1.

School 1 is a Church of England Voluntary Controlled Junior (7-11) school in East Yorkshire, UK. It is a large mixed school, with 378 pupils on the roll. The majority of pupils at the school live on two large council estates nearby and most are of White British origin, with a low proportion of children speaking English as an Additional Language. The latest Ofsted report states that pupil achievement in reading requires improvement and that reading needs to be regularly assessed in order for learning to meet the pupils' needs.

School 2 is a community primary (4-11) school in East Yorkshire, UK. It is a large mixed school, with 350 pupils on the roll. The majority of pupils at the school are of White British origin, with a small number from a wide range of minority ethnic heritages. The school has a low proportion of children speaking English as an Additional Language. The latest Ofsted report states that the school needs to raise attainment in reading.

[Table 1 about here]

Participants for the study were randomly selected from the school's SEN register of pupils on School Action Plus (meaning their progress has been limited and they require the support of external services) for literacy difficulties. Some of the pupils had other co-morbid needs, including numeracy, hearing and behavioural difficulties. Summary data for participants are presented in Table 2.

Participants from School 1 were 18 pupils (12 boys and 6 girls) aged from 7:4 to 11:0, with a mean age of 9:5 (SD=1.14). Participants were matched in pairs on the basis

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of age and gender, with one child from each pair selected at random and placed into the intervention group and the other into the control group. The intervention group consisted of 9 pupils (6 boys and 3 girls) aged from 7:4 to 11:0, with a mean age of 9:6 (SD=1.23). The control group consisted of 9 pupils (6 boys and 3 girls), aged from 7:6 to 10:10, with a mean age of 9:4 (SD=1.11).

Participants from School 2 were 20 pupils (14 boys and 6 girls) aged from 6:7 to 11:0, with a mean age of 8:4 (SD=1.40). Participants were matched in pairs on the basis of age and gender, with one child from each pair selected at random and placed into the intervention group and the other into the control group. The intervention group consisted of 10 pupils (7 boys and 3 girls) aged from 6:7 to 10:9, with a mean age of 8:6 (SD=1.55). The control group consisted of 10 pupils (7 boys and 3 girls), aged from 6:7 to 11:0, with a mean age of 8:2 (SD=1.30).

[Table 2 about here]

2.2 *Materials*

Reading ability was measured using the Neale Analysis of Reading Ability – Revised (NARA-II; Neale, 1997). The NARA-II is an individually administered, standardised reading test, which provides measures of reading accuracy, reading comprehension and reading rate. It is designed for use with 6 to 12 year olds, takes approximately 20 minutes to complete and has two parallel forms. The assessment contains six short stories that increase in length from 26 to 139 words, as well as practice passages for the child to complete in order to ensure that they understand what is required of them before testing begins. Reading of each passage is timed in order to calculate reading rate. Reading errors (mispronunciations, substitutions, refusals,

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additions, omissions or reversals) are noted in order to produce a measure of reading accuracy. Repetitions, hesitations and self-corrections are not counted as errors.

Comprehension questions are asked after each story, which increase in difficulty from literal questions to inferential and evaluative questions. The practice passage and Level 1 passage contain four questions, whilst all other passages contain eight questions. The NARA-II is reported to have good internal consistency with Cronbach's alpha values ranging from 0.81 to 0.87 for reading accuracy and 0.93 to 0.95 for reading comprehension. Parallel form reliability is also adequate, with overall correlations of 0.89 for reading accuracy, 0.82 for reading comprehension and 0.66 for reading rate.

Comprehension Booster (Lucid Innovations, 2010) was used for the reading intervention in this study. Comprehension Booster is a computer program for 7 to 14 year olds, designed to improve reading and listening comprehension, providing practice in reading and understanding texts of different genres and varying difficulty. It comprises 70 fiction passages (and an optional extra 70 non-fiction passages) with accompanying images. Vocabulary support is provided, if a student requests it, for up to 1800 unusual or difficult words. Each passage is followed by a number of multiple choice comprehension questions, including a combination of descriptive and inferential questions. Fig. 1 shows screen shots from the program including a story screen and a question screen.

[Fig. 1 about here]

Comprehension Booster has seven difficulty levels from Starter Level (comprehension age 5-7, 50 word passages, 2 comprehension questions, 0 unusual or difficult words) to Level F (comprehension age 12-14+, 300 word passages, 10

Reading comprehension: A computerised intervention with primary-age poor readers comprehension questions, 25-30 unusual or difficult words). It is an adaptive program in that it responds to the ability of the user – moving on to more difficult levels when students successfully complete levels. The program incorporates digitised speech recordings for all the passages, questions, possible answers and vocabulary support words, for use as required. The program aims to extend vocabulary through the presentation of unusual and difficult words within the passages, with the frequency of these increasing as the child works through the levels. Furthermore, where a child encounters an unusual or difficult word that they are unsure of, they can click on it to have it spoken and a definition provided. In order to work through the levels, students are required to correctly answer comprehension questions which test their ability to extract key information from texts, apply inferential thinking and assimilate complex ideas. At each level of the program, students are required to build on these key reading comprehension skills.

2.3 Procedure

Ethical approval for the study was granted by the Department of Psychology, University of Hull Ethics Committee, in accordance with British Psychological Society guidelines. Researchers involved in data collection underwent a Disclosure and Barring Service check. Consent from the schools' head teachers were gained prior to letters being sent by the school to parents or guardians of the selected children giving the full details of the study and allowing them the option to withdraw their child from it. Before any data collection took place, the children were also verbally informed of the details of the study and told that they did not have to take part if they didn't want to and that they could stop at any time they chose to. Each participant was assigned an ID code by the

school, which was used on the test material and computer program, in order to ensure anonymity.

The NARA-II test was administered pre and post-intervention to measure any changes in reading performance. In order to reduce practice effects and control for order effects, School 1 pupils were administered Form 2 for the pre-intervention test and Form 1 for the post-intervention test, whilst School 2 pupils were administered Form 1 for the pre-intervention test and Form 2 for the post-intervention test. The NARA-II was administered to participants individually in a quiet well-lit room. The test was delivered in accordance with the standardised instructions in the test manual and was discontinued when the child made 16 or more errors on a passage; comprehension questions were not administered on 'failed' passages. Participants were administered the appropriate practice passage for their age group and given the opportunity to ask questions before starting the test. All children in the study started the test on Level 1, regardless of their age, due to their reading ability being below average. The tests were scored in accordance with the test manual.

The week following the pre-intervention reading tests, the intervention groups started the intervention using the Comprehension Booster program, on a group basis, under the supervision of a researcher and teacher or teaching assistant within the schools' networked computer suites. Participants in School 1 used the program for one 30-minute session each week; whilst participants in School 2 used the program for two 30-minute sessions per week. All of the participants in the intervention groups completed all of the Comprehension Booster sessions. The intervention period lasted for six weeks in both schools. The computers used a 1280 x 1024 screen resolution and headphones were available on each computer for the pupils to listen to text where they

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chose to. The default settings (white background, Verdana font, font size of 20 point at Starter level to 14 point at Level F) were initially set up for each participant, although they were encouraged to change these if they wished at any point. All participants in the intervention started on the Starter Level, due to their below average reading ability.

They were able to refer to the text when answering the comprehension questions and were required to pass a level in order to move onto the next. The intervention program incorporated the optional non-fiction passages, as well as the standard fiction passages, so that participants could choose the type of text that they preferred. The control group did not take part in the intervention and, instead, continued with their usual SEN provision, which varied according to individual need but mostly involved individual or small group teaching outside of the classroom, with a focus on phonics.

At the end of the intervention period, all participants were re-administered the NARA-II using the same procedure as previously stated. On completion of the study, the participants were thanked for taking part and debriefed with regard to the expectations of the study. In order that the participants in the control group were not disadvantaged by not having taken part in the intervention, participants in this group (and other pupils in the school) were given access to the program for the following half term (six-week period).

2.4 *Statistical methods*

Three mixed ANOVAs (analysis of variance) are used to test group differences in terms of improvements made from baseline to post-test in reading accuracy, reading comprehension and reading rate. The between-subjects IVs are group (intervention versus control), school (School 1 versus School 2) and age group (6-8 year olds versus

9-11 year olds), whilst the within-subjects IV is time (baseline versus post-test). The DVs are reading accuracy, reading comprehension and reading rate. Cohen's d (Standard Mean Difference) is used as a measure of effect size to compare differences from baseline to post-test for the intervention and control groups. Partial eta squared is used as a measure of effect size for the interactions.

3 Results

Descriptive statistics based on the Standard Scores for each NARA-II reading subscale (accuracy, comprehension and rate) for each group are shown in Table 3.

The mean standard scores for the intervention and control groups on each reading measure at baseline and post-test are shown in Fig. 2.

[Fig. 2 about here]

Due to the differences between schools in the amount of time spent each week on the intervention programme, school was included as an IV in the analysis. The mean standard scores for both intervention groups on each reading measure at baseline and post-test are shown in Fig. 3.

[Fig. 3 about here]

Due to the wide age range of the children in this study, age group was included as an IV in the analysis, with comparisons being made between the mid primary children (6-8 year olds) and the late primary children (9-11 year olds). The mean

standard scores for both age groups from the intervention sample on each reading measure at baseline and post-test are shown in Fig. 4.

[Fig. 4 about here]

Prior to any further analysis taking place, the data were checked for normality (using the Kolmogorov-Smirnov test), homogeneity of variance (using Levene's test) and outliers (using boxplots). The Kolmogorov-Smirnov test shows that the distribution of data for each of the variables are not significantly different from a normal distribution. Levene's test shows that the assumption of homogeneity of variance has not been broken for any pairwise comparison on any variable. Two outliers were identified (a high score on pre-intervention reading comprehension for an intervention group participant and a high score on pre-intervention reading rate for a control group participant). The effect of these outliers will be shown below.

3.1 *Reading accuracy*

The ANOVA for reading accuracy shows a significant main effect of time ($F[1,30]=19.82, p<.001, d=0.34$), with scores increasing from baseline ($M = 81.7, SD = 10.58$) to post-test ($M = 85.4, SD = 11.19$). There is no main effect of group ($F[1,30]=.52, NS$). There is a significant interaction between group and time ($F[1,30]=24.80, p<0.001, \eta^2_p=.45, d=0.72$), with the mean standard score for the control group remaining stable from baseline ($M = 81.3, SD = 11.99$) to post-test ($M = 81.2, SD = 10.94; t[18]=0.178, NS, d=0.01$), whilst the intervention group mean significantly increases from baseline ($M = 82.1, SD = 9.27$) to post-test ($M = 89.6, SD = 9.99; t[18]=5.495, p<.001, d=0.79$).

There is no main effect of school on reading accuracy ($F[1,30]=1.36$, NS). There is a significant interaction between school, group and time ($F[1,30]=11.94$, $p<.01$, $\eta^2_p=.29$). As seen in Table 3, the means for the control groups do not significantly increase for School 1 from baseline ($M = 78.9$, $SD = 12.73$) to post-test ($M = 79.3$, $SD = 10.39$, $t[8]=0.34$, NS, $d=0.04$), or for School 2 from baseline ($M = 83.5$, $SD = 11.49$) to post-test ($M = 82.8$, $SD = 11.70$, $t[9]=.57$, NS, $d=0.06$). However, the mean standard score for the School 1 intervention group significantly increases from baseline ($M = 82.7$, $SD = 7.87$) to post-test ($M = 85.7$, $SD = 8.49$; $t[8]=3.84$, $p<.01$, $d=0.37$), whilst the School 2 intervention group mean increases even more significantly from baseline ($M = 81.5$, $SD = 10.77$) to post-test ($M = 93.2$, $SD = 10.28$; $t[9]=7.05$, $p<.001$, $d=1.11$).

There is no main effect of age group on reading accuracy ($F[1,30]=.03$, NS). There is also no significant interaction between age group, group and time ($F[1,30]=0.27$, NS, $\eta^2_p=.01$). The mean standard scores for the control groups remain stable for 6-8 year olds from baseline ($M = 81.1$, $SD = 13.07$) to post-test ($M = 80.9$, $SD = 12.01$; $t[10]=0.13$, NS; $d=0.01$) and for 9-11 year olds from baseline ($M = 81.6$, $SD = 11.20$) to post-test ($M = 81.5$, $SD = 10.06$; $t[7]=0.14$, NS; $d=0.01$). However, the mean standard scores for the intervention groups significantly increase for 6-8 year olds from baseline ($M = 82.5$, $SD = 8.62$) to post-test ($M = 93.5$, $SD = 9.61$; $t[7]=4.80$, $p<.01$; $d=1.21$) and for 9-11 year olds from baseline ($M = 81.7$, $SD = 10.12$) to post-test ($M = 86.8$, $SD = 9.71$; $t[10]=3.83$, $p<0.01$; $d=0.51$).

3.2 *Reading comprehension*

The ANOVA for reading comprehension shows a significant main effect of time ($F[1,30]=11.81$, $p<.01$, $d=0.33$), with scores increasing from baseline ($M = 82.6$, $SD =$

12.06) to post-test ($M = 86.9$, $SD = 14.42$). There is no main effect of group ($F[1,30]=1.13$, NS). There is a significant interaction between group and time ($F[1,30]=10.17$, $p<.01$, $\eta^2_p=.25$, $d=0.78$), with the mean standard score for the control group remaining relatively stable from baseline ($M = 80.6$, $SD = 11.21$) to post-test ($M = 80.3$, $SD = 12.07$; $t[18]=.46$, NS, $d=0.03$), whilst the intervention group mean significantly increases from baseline ($M = 84.5$, $SD = 12.86$) to post-test ($M = 93.6$, $SD = 13.73$; $t[18]=4.17$, $p<.01$, $d=0.68$). When excluding the outlier on this variable, the result is similar ($F[1,29]=9.92$, $p<.01$, $d=0.87$), indicating that it has had little effect on this outcome.

There is no main effect of school on reading comprehension ($F[1,30]=1.66$, NS). There is a significant interaction between school, group and time ($F[1,30]=10.59$, $p<.01$, $\eta^2_p=.26$). As seen in Table 3, the means for the control groups do not significantly increase for School 1 from baseline ($M = 78.2$, $SD = 11.67$) to post-test ($M = 77.7$, $SD = 12.37$, $t[8]=.40$, NS, $d=0.05$), or for School 2 from baseline ($M = 82.8$, $SD = 10.92$) to post-test ($M = 82.6$, $SD = 11.94$, $t[9]=0.21$, NS, $d=0.02$). The mean standard score for the School 1 intervention group shows no significant increase from baseline ($M = 86.3$, $SD = 11.55$) to post-test ($M = 90.3$, $SD = 13.48$; $t[8]=1.16$, NS, $d=0.32$), whilst the School 2 intervention group mean does significantly increase from baseline ($M = 82.9$, $SD = 14.34$) to post-test ($M = 96.5$, $SD = 13.97$; $t[9]=7.28$, $p<.001$, $d=0.96$). When excluding the outlier on this variable, the result is similar ($F[1,29]=10.31$, $p<.05$, $\eta^2_p=.26$), indicating that it has had little effect on this outcome.

There is no main effect of age group on reading comprehension ($F[1,30]=.84$, NS). There is also no significant interaction between age group, group and time ($F[1,30]=0.43$, NS, $\eta^2_p=.01$). The mean standard scores for the control groups remain

stable for 6-8 year olds from baseline ($M = 80.8$, $SD = 10.76$) to post-test ($M = 80.6$, $SD = 11.85$; $t[10]=0.28$, NS; $d=0.02$) and for 9-11 year olds from baseline ($M = 80.4$, $SD = 12.56$) to post-test ($M = 79.9$, $SD = 13.17$; $t[7]=0.34$, NS; $d=0.04$). The mean standard scores for the intervention groups increase for 6-8 year olds from baseline ($M = 81.8$, $SD = 8.83$) to post-test ($M = 93.0$, $SD = 13.44$; $t[7]=2.62$, $p<.05$; $d=0.99$) and for 9-11 year olds from baseline ($M = 86.6$, $SD = 15.24$) to post-test ($M = 94.0$, $SD = 14.57$; $t[10]=3.43$, $p<.01$; $d=0.50$). When controlling for the outlier on this variable, the result is similar ($F[1,29]=0.41$, NS, $\eta^2_p=.02$), suggesting that it has had little effect on this outcome.

3.3 *Reading rate*

The ANOVA for reading rate shows no main effect of time ($F[1,30]=0.30$, NS, $d=0.14$), with scores remaining stable from baseline ($M = 84.5$, $SD = 11.21$) to post-test ($M = 86.1$, $SD = 11.16$). There is also no main effect of group ($F[1,30]=1.47$, NS) and no significant interaction between group and time ($F[1,30]=1.74$, NS, $\eta^2_p=.055$, $d=0.74$). However, whilst the mean standard score for the intervention group remains relatively stable from baseline ($M = 85.2$, $SD = 8.95$) to post-test ($M = 82.5$, $SD = 9.93$; $t[18]=1.07$, NS, $d=0.29$), the control group mean significantly increases from baseline ($M = 83.8$, $SD = 13.31$) to post-test ($M = 89.6$, $SD = 11.41$; $t[18]=2.28$, $p<.05$, $d=0.47$). When excluding the outlier on this variable, the result is similar ($F[1,29]=2.37$, NS, $d=0.92$), suggesting that it has had little effect on this outcome.

There is no main effect of school on reading comprehension ($F[1,30]=1.68$, NS). There is also no significant interaction between school, group and time ($F[1,30]=0.18$, NS, $\eta^2_p=.01$). As seen in Table 3, the control groups' means do not significantly

increase for School 1 from baseline ($M = 80.0$, $SD = 11.38$) to post-test ($M = 85.0$, $SD = 10.27$, $t[8]=1.31$, NS, $d=0.46$), or for School 2 from baseline ($M = 87.3$, $SD = 14.54$) to post-test ($M = 93.8$, $SD = 11.21$, $t[9]=1.82$, NS, $d=0.50$). There are also no significant increases in the mean standard score for the intervention groups for School 1 from baseline ($M = 84.9$, $SD = 10.78$) to post-test ($M = 83.4$, $SD = 11.37$; $t[8]=0.33$, NS, $d=0.13$), or for School 2 from baseline ($M = 85.4$, $SD = 7.53$) to post-test ($M = 81.6$, $SD = 8.97$; $t[9]=1.28$, NS, $d=0.46$). When excluding the outlier on this variable, the result is similar ($F[1,29]=0.38$, NS, $\eta^2_p=.01$), indicating that it has had little effect on this outcome.

There is no main effect of age group on reading rate ($F[1,30]=0.07$, NS). There is also no significant interaction between age group, group and time ($F[1,30]=0.04$, NS, $\eta^2_p=.001$). The control groups' mean standard scores remain stable for 6-8 year olds from baseline ($M = 84.2$, $SD = 14.70$) to post-test ($M = 91.5$, $SD = 12.26$; $t[10]=2.04$, NS; $d=0.54$) and for 9-11 year olds from baseline ($M = 83.4$, $SD = 12.12$) to post-test ($M = 87.1$, $SD = 10.37$; $t[7]=1.02$, NS; $d=0.33$). The intervention groups' mean standard scores also remain stable for 6-8 year olds from baseline ($M = 84.3$, $SD = 7.85$) to post-test ($M = 83.8$, $SD = 11.07$; $t[7]=0.23$, NS; $d=0.05$) and for 9-11 year olds from baseline ($M = 85.8$, $SD = 9.99$) to post-test ($M = 81.6$, $SD = 9.46$; $t[10]=1.05$, NS; $d=0.44$). When controlling for the outlier on this variable, the result is similar ($F[1,29]=.001$, NS, $\eta^2_p=.001$), suggesting that it has had little effect on this outcome.

4 Discussion

The gains found for the intervention group in reading accuracy and comprehension support the first hypothesis and are in line with previous research showing the effectiveness of computerised reading intervention programs (Gibson et al., 2011; Kim et al., 2006; Torgesen et al., 2010). These findings support the use of silent reading (Kuhn, 2004; Reutzel et al., 2008; Reutzel et al., 2012), repeated reading (Armstrong & Hughes, 2012; Karweit & Wasik, 1996; Therrien et al., 2006), controlled decodable vocabulary and vocabulary instruction (Karweit & Wasik, 1996; Lovett et al., 2003), reading along with the computer (Basil & Reyes, 2003; Swanson et al., 2011), increasingly difficult texts (Chard et al., 2002), question and answering (Karweit & Wasik, 1996) and immediate corrective feedback (Chard et al., 2002; Hall et al., 2000) as an effective combined method of improving reading comprehension. However, due to the nature of the intervention, it is not possible to ascertain which of these techniques is responsible for the improvement in reading accuracy and comprehension.

As expected, the intervention group in School 2, receiving two Comprehension Booster sessions per week, showed significantly bigger gains in reading accuracy and reading comprehension than the intervention group in School 1, who only received one Comprehension Booster session per week. This supports the finding of Galushcka et al. (2014) in their meta-analysis of reading trials, that interventions with higher amounts of treatment are more effective in improving literacy skills. The only effects of age are that the younger age group (6-8 year olds) showed a bigger increase in reading accuracy, as a result of the intervention, whilst the older age group (9-11 year olds) showed a bigger increase in reading comprehension. Both groups remained stable on reading rate. The National Reading Panel report (NICHHD, 2000) shows that interventions are not

equally effective for different age groups and providing an intervention to children within a wide age span is not recommended (Galuschka et al., 2014). However, the Comprehension Booster program has been shown to be effective in increasing reading comprehension in both age groups within this study, suggesting that it is suitable for the 6-11-year-old age range.

It was expected that reading rate would not significantly improve for either the intervention or the control group. However, the results show that reading rate actually increased for the control group, but remained stable for the intervention group. The NARA manual states that parallel form reliability is lowest for reading rate (0.66), which may have impacted on these data. Nevertheless, Carver (1992) found that readers adjust their reading speed according to the goal – speeding up if they are scanning for a particular word and slowing down if they want to memorise concepts, with a middle gear which is optimal for comprehension. The participants in the intervention group may have become more familiar with completing comprehension tasks as a result of the intervention and, as they knew they were going to be asked questions on the passages, may have slowed down to improve their comprehension.

The effect sizes (Cohen's *d*) comparing the differences from pre to post intervention between the intervention and control groups are 0.72 (medium effect) for reading accuracy and 0.78 (medium effect) for reading comprehension. These exceed the effect sizes reported by Swanson (1999), who carried out a meta-analysis of intervention studies with children with learning difficulties and found average effect sizes of 0.62 for word recognition and 0.45 for reading comprehension for studies using standardised (rather than experimental) outcome measures. They also surpass Torgesen et al.'s (2010) reported effect sizes of 0.53 (word reading accuracy) and 0.40 (passage

comprehension) following a longer and more intensive intervention (four 50-minute sessions per week for a 7-month period). The effect size for reading comprehension in the current study also far exceeds the 0.50 effect size found by Kim et al. (2006) for passage comprehension and the small effect size (0.18) found by Galuschka et al. (2014) for the three reading comprehension trials within their meta-analysis.

However, Torgesen et al. (2001) suggest that effect sizes merely describe the advantage in reading growth for children in an intervention group compared to a control group – they do not tell us anything about rate of normalisation of reading skills. Instead, Torgesen et al. suggest that changes in standard scores show evidence of how much reading skills differ to those of average readers at the end of the intervention. Indeed, McGuiness, McGuiness and McGuiness (1996) stated that the effectiveness of interventions should be reported in terms of standard score increase per hour of instruction. In the current study, participants in the intervention group showed mean gains of 1.00 SS per hour (School 1) and 1.96 SS per hour (School 2) for reading accuracy; and 1.33 SS per hour (School 1) and 2.27 SS per hour (School 2) for reading comprehension. These compare favourably to SS gains reported by other researchers. Torgesen et al. (2001) reviewed several studies and found SS gains per hour of intervention ranging from 0.13 to 0.23 for word identification, and 0.12 to 1.7 for passage comprehension. Of the studies reviewed by Torgesen et al., the only one utilising a computer-based intervention was that of Wise et al. (1999, cited in Torgesen et al., 2001), which reported SS gains per hour of intervention of 0.22 (word identification) and 0.15 (passage comprehension). The remaining studies reviewed by Torgesen et al. used non-computerised interventions and so were much more resource intensive than the intervention used in the current study. Torgesen et al. (2001) suggest

that the SS gains per hour of intervention found for the two interventions used in their own study “could serve as a benchmark for ‘reasonable progress’ in reading for students receiving remedial instruction” (p. 52). These gains were 0.20-0.21 for word identification and 0.12-0.15 for passage comprehension. It is clear that the gains shown in the current study far exceed these.

Brooks (2002) states that rates of progress at double the standard rate (i.e. 2 years gain in 12 months) should be expected from intervention studies. However, Bunn (2008) suggests that this is over-optimistic. Nevertheless, in the current study, pupils in the intervention group made mean gains of 9 months in reading accuracy (mean reading accuracy age pre-intervention = 7:01; post-intervention = 7:10) and 12 months in reading comprehension (mean reading comprehension age pre-intervention = 7:06; post-intervention = 8:06) in a six-week period. These far exceed Brooks’ requirement of 3 month gains within this period.

However, several limitations of this study must be considered before any conclusions are made. The first limitations are with the sample. The study utilised a small sample size which limits its statistical power. Furthermore, the limited sample size meant that it was not possible to compare different types of poor reader (i.e. poor reading comprehenders versus poor decoders versus individuals who are poor at both decoding and comprehension). Future research should be conducted with a large enough sample to allow for stratification based on reading level and difficulty type.

Additionally, the study is limited to one geographical location, with the schools both being in an area of disadvantage, and so the findings may not be generalisable to children from more affluent backgrounds. Furthermore, the study only involved English participants. The requirements for acquiring proficiency as a reader vary between

different orthographies (Marinelli, Horne, McGeown, Zoccolotti & Martelli, 2014).

Marinelli et al. (2014) found English (opaque orthography) readers to be more variable in terms of reading speed than Italian (transparent orthography) readers. They suggest that this is a specific characteristic of English readers as the opaque orthography and complex syllabic structure mean that readers use a variety of different strategies, resulting in differential reading efficiency. Therefore, different results to those found in the current study, particularly with regard to reading rate, may be gained in studies with participants using transparent orthographies.

The second set of limitations involves the intervention itself. The study utilised a short six-week intervention and no long-term follow-up data were collected. Although the scores of the intervention group significantly increased on reading accuracy and comprehension, scores were still not at the level expected for chronological age. A longer intervention would be required to see if this is possible and follow-up data is necessary to establish whether the improvements remain beyond the intervention period. Also the intensity of the intervention in the current study was not standard across the two schools and a more intense intervention (e.g. 2 x one hour sessions per week) could be utilised. Furthermore, the current study only investigated one intervention and so it is not possible to directly compare its effectiveness to other interventions.

The third set of limitations relates to the outcome measures utilised. The study only measured reading pre and post intervention and did not look at changes in other variables, such as word reading, working memory, vocabulary, spelling, listening comprehension, reading confidence and reading motivation. Spelling and reading difficulties are likely to be caused by the same underlying deficits, so an intervention targeting reading deficits may positively impact on spelling ability. Indeed, Saine et al.

(2013) found that a computer-assisted reading intervention raised the spelling levels of at-risk children to that of mainstream children.

Future research is required to compare the Comprehension Booster program to other conventional and computerised intervention programs using a larger sample, conduct continuous testing throughout an increased intervention period in order to determine the optimal length of program through the use of growth modelling, continue testing beyond the intervention period in order to determine the length of intervention necessary to prevent a 'relative decline' in reading after the intervention has been withdrawn, and administer a wider range of outcome measures to determine the effect of the intervention on word reading, spelling, vocabulary, working memory, listening comprehension, reading confidence and reading motivation.

5 *Conclusions*

Computerised reading programs that are shown through empirical research to be effective in improving reading skills are useful as additional tools for pupils with reading difficulties, particularly in disadvantaged areas where resources are limited and family support in reading lower. The gains shown in reading accuracy and comprehension in the current study are significant in only a short intervention period of six weeks. The program used here can be integrated within the primary school day, carried out on a group basis in networked computer rooms with minimal supervision, and is individualised. Children at risk of reading difficulties can be identified at school entry and could benefit from the use of a computerised reading intervention program.

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However, this is not a replacement for good teaching, and regular monitoring of children with reading difficulties is required.

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Table 1: School summary data

| | School 1 | School 2 | National average |
|---|-----------|-----------|---------------------|
| Number on roll (n/Quintile) | 378 / Q2 | 350 / Q2 | 257 |
| Female (%/Quintile) | 49.7 / Q3 | 44.0 / Q5 | 49.0 |
| FSM (%/Quintile) | 27.2 / Q2 | 48.9 / Q1 | 26.7 |
| SEN (%/Quintile) | 10.8 / Q2 | 19.7 / Q1 | 7.7 |
| Attendance (%/Quintile) | 95.7 / Q2 | 93.3 / Q5 | 95.2 |
| Reading – level 4 or above (%/Quintile) | 81 / Q4 | 84 / Q4 | 86 |
| Reading – disadvantaged pupils achieving level 4 or above (%) | 74 | 73 | 86 |
| Reading – non-disadvantaged pupils achieving level 4 or above (%) | 84 | 100 | 86 |
| Reading – achieved expected progress (%/Quintile) | 84 / Q4 | 75 / Q5 | 88 |
| Reading – disadvantaged pupils achieving expected progress (%) | 80 | 70 | 88 |
| Reading – non-disadvantaged pupils achieving expected progress (%) | 86 | 81 | 88 |

Q1=top 20%; Q2=top 40%; Q3=middle 20%; Q4=bottom 40%; Q5=bottom 20%

Table 2: Participant summary data

| | Males | Females | Min age | Max age | Mean age (SD) |
|-----------------------|-------|---------|---------|---------|---------------|
| School 1 Intervention | 6 | 3 | 7:4 | 11:0 | 9:6 (1.23) |
| School 1 Control | 6 | 3 | 7:6 | 10:10 | 9:4 (1.11) |
| School 1 Total | 12 | 6 | 7:4 | 11:0 | 9:5 (1.14) |
| School 2 Intervention | 7 | 3 | 6:7 | 10:9 | 8:6 (1.55) |
| School 2 Control | 7 | 3 | 6:7 | 11:0 | 8:2 (1.30) |
| School 2 Total | 14 | 6 | 6:7 | 11:0 | 8:4 (1.40) |
| Total Intervention | 13 | 6 | 6:7 | 11:0 | 9:0 (1.47) |
| Total Control | 13 | 6 | 6:7 | 11:0 | 8:6 (1.32) |
| Total Overall | 26 | 12 | 6:7 | 11:0 | 8:10 (1.38) |

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Table 3: Descriptive statistics: Standard Scores for all groups

| | Control | Intervention | Control (School 1) | Intervention (School 1) | Control (School 2) | Intervention (School 2) | Control (age 6-8) | Intervention (age 6-8) | Control (age 9-11) | Intervention (age 9-11) |
|--------------------|--------------|--------------|-----------------------|----------------------------|-----------------------|----------------------------|----------------------|---------------------------|-----------------------|----------------------------|
| Pre Accuracy | | | | | | | | | | |
| Min/Max | 69 / 103 | 69 / 98 | 69 / 101 | 69 / 96 | 69 / 103 | 69 / 98 | 69 / 103 | 69 / 95 | 69 / 97 | 69 / 98 |
| Mean (SD) | 81.3 (11.99) | 82.1 (9.27) | 78.9 (12.73) | 82.7 (7.87) | 83.5 (11.49) | 81.5 (10.77) | 81.1 (13.07) | 82.5 (8.62) | 81.6 (11.20) | 81.7 (10.12) |
| Pre Comprehension | | | | | | | | | | |
| Min/Max | 69 / 102 | 69 / 116 | 69 / 101 | 75 / 112 | 69 / 102 | 69 / 116 | 69 / 102 | 69 / 93 | 69 / 100 | 69 / 116 |
| Mean (SD) | 80.6 (11.21) | 84.5 (12.86) | 78.2 (11.67) | 86.3 (11.55) | 82.8 (10.92) | 82.9 (14.34) | 80.8 (10.76) | 81.8 (8.83) | 80.4 (12.56) | 86.6 (15.24) |
| Pre Rate | | | | | | | | | | |
| Min/Max | 69 / 115 | 69 / 101 | 69 / 102 | 69 / 96 | 69 / 115 | 78 / 101 | 69 / 115 | 70 / 95 | 69 / 104 | 69 / 101 |
| Mean (SD) | 83.8 (13.31) | 85.2 (8.95) | 80.0 (11.38) | 84.9 (10.78) | 87.3 (14.54) | 85.4 (7.53) | 84.2 (14.70) | 84.3 (7.85) | 83.4 (12.12) | 85.8 (9.99) |
| Post Accuracy | | | | | | | | | | |
| Min/Max | 69 / 106 | 71 / 104 | 69 / 97 | 71 / 100 | 69 / 106 | 79 / 104 | 69 / 106 | 81 / 104 | 69 / 97 | 71 / 104 |
| Mean (SD) | 81.2 (10.94) | 89.6 (9.99) | 79.3 (10.39) | 85.7 (8.49) | 82.8 (11.70) | 93.2 (10.28) | 80.9 (12.01) | 93.5 (9.61) | 81.5 (10.06) | 86.8 (9.71) |
| Post Comprehension | | | | | | | | | | |
| Min/Max | 69 / 104 | 72 / 122 | 69 / 101 | 72 / 114 | 69 / 104 | 79 / 122 | 69 / 104 | 77 / 113 | 69 / 101 | 72 / 122 |
| Mean (SD) | 80.3 (12.07) | 93.6 (13.73) | 77.7 (12.37) | 90.3 (13.48) | 82.6 (11.94) | 96.5 (13.97) | 80.6 (11.85) | 93.0 (13.44) | 79.9 (13.17) | 94.0 (14.57) |
| Post Rate | | | | | | | | | | |
| Min/Max | 69 / 110 | 69 / 100 | 69 / 97 | 69 / 97 | 76 / 110 | 69 / 100 | 73 / 110 | 69 / 100 | 69 / 97 | 69 / 96 |
| Mean (SD) | 89.6 (11.41) | 82.5 (9.93) | 85.0 (10.27) | 83.4 (11.37) | 93.8 (11.21) | 81.6 (8.97) | 91.5 (12.26) | 83.8 (11.07) | 87.1 (10.37) | 81.6 (9.46) |